portation of cold or warm air can also often be detected by comparing the noon temperature with the temperature at 6 p. m. The difference between these two temperatures varies with the season, but in April, in rural exposures in this district, the temperature at 6 p. m. is normally 7 degrees lower than at noon. If, for example, the temperature at 6 p. m. is 10 degrees lower than at noon, it is assumed that during the 6 hours there has been an inflow of cold air sufficient to reduce the temperature 0.5 degree per hour. Whether such cooling was active throughout the six hours can often be determined from the thermograph trace. The use of these methods presupposes that the cooling or warming will continue throughout the night, which is not always the case. Where the reception of solar radiation is materially interfered with by cloudiness during the afternoon the method has no value.

The condition of the ground as regards moisture is also a factor to be considered. A rain will materially lessen the range of temperature for the following night, and probably for several nights, depending on the amount of moisture retained by the ground. It will also reduce the irregular variations in both number and amplitude.

The dewpoint is so infrequently reached that the forecaster can usually afford to ignore it. In the spring the average difference between the minimum temperature and the morning dewpoint is 18 degrees.

It was stated in a preceding paragraph that there are exceptions to the rule that the normal minimum will be very nearly reached on nights favorable to radiational cooling. One of these exceptions is where the wind, which is normally westerly during the first half of the night, continues from the same general direction throughout the night. This is due, of course, to an increasing pressure gradient from east to west across New Mexico, but it is often difficult to know whether or not such gradient will be sufficient to control the wind direction during the second half of the night. It may develop during the night, when such development can not be foreseen on the preceding day. This is likely to modify greatly the course of the temperature after midnight, and minimum temperature forecasts on such occasions may be as much as 10 or 12 degrees in error. A single example of this is presented in figure 4, for the night of March 23–24, 1918. The broken line here represents the normal cooling, as calculated at 9 p. m. the evening before. Also, with westerly winds, the minimum temperature is likely to occur at any time between midnight and morning. In figure 6, traces M to P, the minimum of each trace was due to a temporary shift of the wind to east or northeast.

The second exception to the rule is where a late shift of the wind to northeast occurs. Traces B, D, J, K, and L, of figure 6, may serve as illustrations.

Temperature irregularities due to the mixing of the lower and upper air or to the unequal cooling of the lower air do not materially affect the minimum, except in the case where such a fluctuation occurs at the time of minimum temperature. This unequal cooling is normally most pronounced early in the morning, and the temperature variations due thereto may be considerable, but as a rule they are not of sufficient amplitude to destroy the value of the forecast.

Most of the local orchardists who practice orchard heating are equipped to meet successfully any low temperature that is likely to occur. Consequently they are as much interested in knowing at what hour of the night the temperature will reach a critical degree as in knowing what the minimum is likely to be. Owing to the usual extreme irregularity of the night thermograph trace on nights favorable to radiational cooling, it is easier to calculate the temperature for different hours of the night when there is a decided inflow of cold air. In spring, however, the temperature rarely reaches a critical point before 4 a. m., and the temperature at this hour can be calculated with a greater degree of accuracy than for any preceding hour back to midnight. This is because, as has been stated, the temperature on "radiation" nights tends to regain its normal path in the early morning hours.

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## ICE STORMS IN THE SOUTHERN APPALACHIANS.

Verne Rhoades, Forest Examiner in Charge Pisgah Purchase Area.

Numerous brief records have been made from time to time relating to the severity of ice storms in various sections of the United States. So far as the writer is acquainted with the accounts of such atmospheric disturbances published in this country, none of them speaks of damage to tree growth as being as widespread or so injurious in their effects as that which was occasioned by an ice storm which passed over the hardwood region of a portion of western North Carolina and northwestern South Carolina in the early spring of 1915.

A rain began falling at 6 p. m. on March 4, 1915, and about midnight the temperature dropped to freezing. The rain thereupon turned to sleet, and for the ensuing 24 hours, from midnight on the 4th to midnight on the 5th, the precipitation was practically continuous either as rain or as sleet. A heavy coating of ice encased the branches, both large and small, of all trees found within the compass of the storm, which followed a general southwesterly direction in the vicinity of Hendersonville, Saluda, and Tryon, N. C.

At the higher elevations in the mountains—in Pisgah Forest, for example—the greatest amount of damage to tree growth was on the slopes facing the south and east. In the valleys the severity of the storm was felt alike on the hills and along the streams.

On the following morning the chestnut and oak slopes showed a vast array of whitened, splintered tops and trunks where the limbs had been torn away. It was a striking, though not a pleasing, picture. It was an easy matter for one to stand in one spot and count hundreds of trees which had lost a portion or all of their tops and branches because of the weight of the accumulated ice. In the heads of some of the coves in Pisgah Forest the ice on the ground was 20 inches or more in depth where it had fallen from the trees. In numerous instances white oak, chestnut oak, and red oak with their strong fibers were broken off sheer at a height of 20 feet from the ground. One 16-inch white oak was observed in a small opening in the surrounding forest with its trunk snapped in two. No defect contributed to its fall. The number of trees in the region which plainly showed the marks of the ice storm must have totaled in the hundreds of thousands.

Apparently no one species withstood the shock of the ice better than another. This observation applies particularly to the mixture of the species where the ice deposit was the heaviest. Probably more chestnut trees were injured than any other species. This was due probably to the fact that chestnut is numerically the leading species in the region rather than to any brittle quality of its wood. Young trees with flexible branches suffered as severely as did old trees of stiffened fiber.

Oaks of all species, chestnut, basswood, yellow poplar, white pine, yellow pine, and even hickory were hard hit. Second-growth yellow poplar coming up in dense stands in certain localities had 90 per cent of their number injured beyond recovery. Similarly in the case of chestnut, particularly chestnut coppice sprouts. Oaks were stripped of their branches. Yellow poplars of pole and standard size frequently broke squarely off below their crowns. Hickory was bent far over with interlocking limbs. Trees with twining vines were broken in two or borne down past recovery.

Had there been a heavy wind immediately following the storm the damage resulting would have been little short of disastrous. It is possible that where certain species, as the oaks, were broken off there may have been gusts of wind which increased the severity of the damage locally. Some of the trees which were merely bent over would have subsequently recovered, probably, if the sudden putting forth of the foilage a few weeks later had not held them down through sheer weight of the leaves. In support of this statement it was noticed by the forest officers in Pisgah Forest that many young trees which were borne down by the ice until their crowns were within a few feet of the ground, bent down after the coming of the leaves until their crowns touched the ground. Such trees can not now regain their former erect position.

In some of the large white pine groves on the private estates about Hendersonville and Flat Rock, N. C., the damage was also excessive. Although over a year has passed since the date of the storm, even now the men in charge of these estates have not been able to rid the groves and woodlands of the ragged appearance of the stands. The effects of the ice will be noticeable for a long time to come. Already the southern barkbeetle (*Dendroctonus frontalis*) has destroyed a large number of the pines. It may be reasonably anticipated that the injured hardwoods will more rapidly deteriorate through the action of fungi which may now find easy access to the interior of the trees.

The shattered tops in Pisgah Forest bear evidence of greater damage from natural causes than all the timber-felling crews would make in many years of careless cutting.

### NOTE ON THE PRECEDING.

Mr. Rhoades describes very clearly the damage by ice to the timber in the vicinity of Hendersonville and Saluda, N. C. Unfortunately ice storms [1] of this kind are by no means infrequent in the Appalachians south of Pennsylvania. I have been struck in examining a great deal of the old forest, especially that of the mountain slopes between elevations of 1,200 and 4,000 feet, with the general prevalence of ice damage to the timber. In the mountains an ice storm is often limited to a belt or zone which may have an altitudinal range of only a few hundred feet, it being possibly so cold above this elevation that the rain falls as snow or hail, and so warm below it that there is no freezing; yet such a storm may extend for many miles along the mountains within this narrow belt.

Over certain sections, as on the Massanutten and Shenandoah Mountains in Virginia, the general appearance of the forest seems to indicate that practically all of it has been injured by ice during some period of its existence. It is frequently the case that ice damage occurred so many years ago that the trees have replaced their stripped crowns. There are several signs, however, which indicate that a forest has passed through such a crisis even though it may have been remote. In the case of poplar, linn, cucumber, chestnut, and some other species having comparatively brittle wood, the stubs of the larger branches which were broken are tipped or even feathered with numerous small, mostly adventitious, branches. Oaks and hickories having tougher wood frequently have the entire upper portion of their crowns destroyed by the breaking of their central stems. The ultimate result of this is the development of very broad and flat mushroom-like crowns on trees which have been so mutilated. This form of crown is more lasting than the preceding and after a long period is a surer indication of ice damage. Stands have been examined in which the date of the storm, based on the estimated time of development of the mushroom crowns, was placed more than a hundred years ago. During this interval the branchy crowns of the chestnuts had nearly assumed a normal appearance. In many cases a shoot on a side, often on a nearly horizontal branch, developes into a new leader. In time a new crown of normal shape may form around this leader—but there will be an offset in the stem of the tree at the point of development of the new leader.[1]

Another and very lasting deformation, which takes place particularly in young stands which are so crowded that the stems are slender, is the bending over of the stems without breaking. Under the weight of ice the crowns of slender young hickories, even of trees 60 to 70 feet high, will sometimes touch the ground without the stems breaking. Such bent-over stems seldom right themselves, and since bending in this manner is practically limited to young trees the wood of which has not yet become brittle, it is an indication of ice damage which persists for a very long period. The presence in a stand of a number of old trees which are bowed in this manner is an almost certain sign of past ice damage of great antiquity. At the present time there is on Massanutten Mountain in Shenandoah County, Va., not a great distance from Woodstock, a young stand in which in many places the slender oaks and hickories, many of them 10 to 14 inches in diameter, have been bent into an almost inextricable tangle. On account of the youth of these trees comparatively few were broken. It is safe to say that the signs of this storm will be written in this stand for a century unless the injured trees are cut out.

As Mr. Rhoades states, the breakage by ice is a predisposing cause of diseased timber. It is in fact one of the causes of the large amount of wormy and fungous-infested timber of middle age which is to be found throughout certain sections. For this reason ice damage must be reckoned with as an important factor in developing any system of forest management in certain areas which are prone to such storms. Some of the windshake is also probably traceable to the trees bending or swaying under the stress of ice.

The recognition of ice injury of a distant past date in a stand is frequently extremely important in appraisal. The diseased condition of the tops and the wormy timber result in a material lowering of the grades of lumber below what would normally be looked for in trees having no other external indications of defect. Red oak along upper crests, which might otherwise be expected to cut out largely No. 1 common and better lumber, would contain an unaccountable proportion of sound wormy stock, a defect which is rather unusual for this species. Similar deterioration would take place in other species.—*W. W. Ashe, Forest Inspector Forest Service.*

[1] See article on "Definition of Sleet" in MONTHLY WEATHER REVIEW, May, 1916, 44: 281-286.

[1] In June, 1917, in company with Mr. J. H. Fahrenbach, of the Forest Service, I noted the damage caused to timber along the Blue Ridge Mountains in Amherst County, Va., by a recent ice storm. It was not difficult to select trees which, through the development of such offset leaders, showed that they had been injured by two previous storms, which were apparently about 14 and 35 years before the last one.